Modeling the Operating Speed in Tangents and Curves of Four-lane Highways Based on Geometric and Roadside Factors

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Abstract

Operating speed is an index that represents drivers' speeding behaviors on different highways and shows the comfort and safety levels they experience. Many models had been proposed in previous studies to predict operating speed and most of these works had used geometric, with few of them conducted using roadside variables to predict operating speed. Also, the operating speed study in multilane rural highways had been gained less attention by researchers. In this study, two four-lane rural highways (Kole jub-Borujerd and Borujerd-Khorramabad) had been surveyed for analyzing the operating speed. More than 13,800 spot speed data was gathered in 108 tangent and 30 curve segments. Two linear regression models were developed to predict operating speed in the tangent and curve segments using geometric and roadside factors simultaneously with the acceptable R-squared statistic (0.730 and 0.854 respectively). The results showed that segment length, guardrail median, and flat roadside configuration have a positive effect while slope, accesses density, curvature, and adjacent land use length have a negative effect on operating speed. Moreover, the sensitivity analysis demonstrates that the effect of slope on operating speed in curves is twice comparing to its effect in tangents; while, operating speed in tangents is approximately 2.5 times more sensitive to access density than operating speed in curves. Thus, it can be concluded that not only geometric features affect operating speed but also roadside features affect it. The outcomes of this study can be useful in design and safety planning studies of rural multilane highways.

Keywords: Operating speed; roadside features; geometric features; speed prediction modeling; four-lane highways

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1. Introduction

Operating speed is an index that represents drivers' behaviors on different roads and shows the comfort and safety levels they experience. Operating speed is the representative of three main components of driving; i.e., road, driver, and vehicle. Inconsistency among these components has a negative effect on road safety. Besides, several studies indicated that an increase in vehicles' speed is accompanied by the increase of accident severity or probability of accidents occurrence [Gargoum and El-Basyouny, 2016; Gitelman et al.2017; Mirbaha et al.2013]. In this regard, operating speed has been an appealing issue for road designers for new designs or adjustments. Therefore, a large tendency is growing among researchers to present some models for operating speed Prediction.

There are several definitions for the operating speed in the literature. According to Iranian Highway Geometric Design Code No. 415 (2012):

"Operating speed is a speed chosen by drivers under free traffic flow condition. For all roads and under free-flow traffic condition, this parameter is defined such that 85% of drivers drive at a speed equal to or less than that".

Operating speed has been determined by several studies. These works predict this speed for tangents and curves of the road separately. Moreover, geometric features (segment length, slope, curvature, etc.), roadside features (access density, land use, weather conditions, etc.), and traffic variables (traffic flow, etc.) had been identified as effective factors on operating speed.

Majority of models proposed in the previous studies had predicted operating speed in two-lane rural roads [Boroujerdian et al.2016; Cafiso et al.2010; Esposito et al.2011; Yagar and Aerde, 1983; Zhu and Rong, 2010]. Meanwhile, few studies had been performed on four-lane rural highways [Himes and Donnell, 2010; Semeida, 2013]. Considering that many of two-lane roads are planned to be developed to four-lane highways, it is necessary to predict operating speed in these roads.

In this study, two regression models are proposed for prediction of operating speed in four-lane rural highways considering geometric and roadside features for tangents and curves. The rest of this paper is structured as follows: Section 2 reviews the relevant literature. Sections 3 and 4 present data collection process and theoretical basis of the regression model, respectively. Section 5 gives modeling results. Finally, Section 6 gives some concluding remarks.

2. Literature Review

In the following, some of the most important works conducted on operating speed are presented.

Several studies have employed only geometric features to predict operating speed in tangents. For instance, Boroujerdian evaluated a set of variables effective on operating speed and reported that initial speed and slope are most important factors for the uphill and downhill models [Boroujerdian et al. 2016]. In addition to these variables, they applied posted speed limit in downhill models. Esposito et al. (2011) proposed a model for operating speed prediction and consistency evaluation for horizontal curve and tangent segments of a road in separated models. Segment length, curvature change rate, and slope were found significant in the tangents model.

Praticò and Giunta (2012) proposed a regression model for operating speed prediction for tangents of two-lane highways in rural areas. Among several models presented in their work, the optimum one is as follows:

$$V85 = \left[\frac{a}{R_i} + b\right] + \left[1 - \frac{1}{1 + \left(\frac{L_i}{f}\right)^n}\right] . \left[\frac{1}{1 + \exp\left(\frac{R^* - R_i}{G}\right)}\right] . e + c . g \frac{a'}{R_{i-1}} + F_2(AD) \quad (1)$$

where R_i is the radius of the i_{th} slope, L_i is segment length, g is the gradient, AD is access density, and a, b, c, a′, d′, e, f, n, G, h, R* are constants. The results of this model showed that horizontal curvature, slope, and segment length have the highest effect on operating speed.

In another study, D'Andrea and colleagues studied the variables with maximum effect on operating speed estimation. For this purpose, they investigated several variables including radius of curve, angle of deviation, design speed, available sight distance offered, stopping sight distance required, presence of admission, presence of intersections, horizontal signs, vertical sign, presence of barriers, roughness of the pavement, and visibility of the inner edge. Finally, they reported that available sight distance and stopping sight distance have the highest effect on operating speed [D' Andre et al. 2012].

Another group of studies utilizes geometric features to predict operating speed in the curves since accidents majorly occur in these segments of the roads. In this regard, two-lane roads in rural areas show the highest risk and severity of collisions such that 50-60% of accidents occur in two-lane roads, with half of them occurring in the curves [Azarmi, 2005]. Abbas et al. (2011) conducted a study on operating speed modeling in curves on two-lane roads using a laser gun. The spot speed of vehicles measured in three sections. They showed that curve radius is the most important factor in operating speed of curve segments and they only used curve diameter for operating speed prediction and neglects other geometric features such as lane width, segment length, and so on.

[Hashim et al. 2016] studied geometric design consistency with the aim of identifying the factors affecting the consistency and proposed a speed profile model for two-lane highways in Egypt. They studied tangent and curve segments of roads separately using variables including radius, superelevation, and tangent length. Their results show that curve radius and tangent length immediately before the curves are most important factors on operating speed. Also, similar to previous studies, this study was conducted using only geometric features.

A limited number of studies have investigated operating speed using roadside features. Yagar and Aerde (1983) studied the effect of geometric and roadside features on the speed of two-lane roads. This work is among rare studies that investigate geometric and roadside features simultaneously. The variables used in this study include the access, an extra lane, land use, shoulder width, slope, curvature, posted speed limit, middle line, sight distance, and shoulder width. They showed that land use and posted speed limit has the highest effect on speed in two-lane rural roads. In another study, Bella (2013) investigated the effect of presence of guardrail, sight distance, and change in roadside configuration on driving speed in two-lane roads. For this purpose, they applied a driving simulator and selected different roadside configurations. Their results show that the speed chosen by drivers is affected by segment characteristics and geometric features while the sight distance is affected by roadside configuration.

The existence and number of accesses is another roadside factor that highly affects the operating speed. Zhu and Rong (2010) studied the effect of the number of accesses on operating speed in two-lane roads and showed that access density is a statistically important variable. Using artificial neural network, Semedia (2012) indicated that the existence of side access along with pavement width and the median width are the most influential variables on operating speed in multi-lane highways.

Reviewing the previous studies reveals that some researchers have considered geometric features [Abbas et al. 2011; Boroujerdian et al. 2016; Esposito et al. 2011; Hashim et al. 2016; Praticò and Giunta 2012] and some other have utilized roadside features [Bella, 2013; Yagar and Aerde, 1983; Zhu and Rong 2010] to predict operating speed. But, studies incorporating roadside and geometric features simultaneously for operating speed prediction are very few [Fitzpatrick et al. 2001; Yagar and Aerde, 1983]. However, Fitzpatrick et al. (2001) and Yagar and Aerde (1983) presented prediction models for suburban street and two-lane highways respectively and they did not present a model for four-lane rural highways.

Hence, considering that a large number of two-lane highways are developed into four-lane highways to enhance their safety level and considering the scarcity of studies incorporating roadside and geometric features simultaneously in operating speed prediction, two models are presented in the present work to predict operating speed in tangents and curves of four-lane highways based on simultaneous utilization of roadside and geometric features.

3. Data

Two highways from the main arterial rural roads of Markazi and Lorestan Provinces in Iran were selected as the case study. Toureh-Boroujerd and Boroujerd-Khoramabad are two-way four-lane highways (two lanes in each direction) in mountainous terrain. The total length of these two highways is 135 kilometer (in both directions) and the width of each lane is constant and equal to 3.75 meter along the whole road. Besides, different types of land use (residential, commercial, etc.) were existed along the whole road which is the reason for the existence of different posted speed limit in different locations. For collecting speed data, first, the highway length was segmented based on geometric and roadside features (curves, land use etc.) using Google Earth photos and video images from the highway, segmentation was performed by considering the following parameters:

1. Shifting from tangent to curve
2. Shifting from uphill to downhill
3. Changing more than 1.5% in longitudinal slope
4. Presence of adjacent land use
5. Changing more than 20 km/h in posted speed limit

Based on the above-mentioned parameters, the entire road was segmented into 138 segments. After the segmentation, the spot speed was gathered from 138 segments using a speed gun (type Bushnell) with ± 1 km/h accuracy. In this process, the spot speeds of 100 passenger cars were collected (without gaining the attention of drivers) in the middle of each segment (additionally, more than 13800 spot speed). The data collection was performed during daylight and under appropriate weather conditions. The traffic flow was less than 1000 vehicle per hour and no queue or congestion was observed during the entire data collection process.

After collecting spot speed data, the geometric and roadside factors were collected from all segments in a field survey using a video recording camera and a GPS device. Table 1 shows the descriptive statistics and definition of all variables which were gathered in this research. As can be seen in table 1 in addition to geometric features (segment length, slope, radius, curvature, paved and unpaved shoulder width, paved width) roadside features (access, land use, land use type, median and roadside configuration type, and posted speed limit) were evaluated which to the best of the authors' knowledge have not been considered simultaneously for predicting operating speed in the previous studies.

4. Modeling Approach

In the present study, similar to the previous works [Boroujerdian et al.2016; Garcia et al.2013; Hashim et al.2016; Shallam and Ahmed, 2016], multiple regression modeling was employed. The theoretical principles of regression models are briefly described here:

Regression analysis is a tool to relate two or several variables with each other such that to predict the desired variable using one or more other variables [Gujarati and Porter, 2003].

Multiple linear regression is a model that consists of independent variables that estimate a given dependent variable. In this method, some coefficients are determined for independent variables. The general form of multiple regression models is as Equation (*2*):

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \qquad (2)$$

where Y_i is the dependent variable; $\beta_0, \beta_1, \ldots, \beta_n$ are model coefficients; X_i is the independent variables; and ε is the error term.

There are several criteria to evaluate the performance of the regression models; e.g., R-squared, T-test, F-test, Durbin-Watson test, and Kolmogorov-Smirnov test. All these criteria were used in the present research.

Table 1. Descriptive Statistics of Variables

Variable	**Continuous Variables**					
	Type of variable	Variable Symbol	min	max	Mean	Standard Deviation
Operating speed (km/hr)	Dependent Variable	V85	62.00	110.00	94.05	10.12
Segment length (km)	Geometric Feature	LN	0.20	2.70	1.25	0.70
Natural logarithm of the Segment length		LOGLN	2.30	3.83	3.04	0.20
Slope (%)		SLP	-7.80	14.36	0.21	3.88
Radius (m)		R	87.00	1000.00	851.03	288.80
Curvature ($\frac{1}{radius} * 1000$)		C	0.00	11.5	0. 822	1.8144
Paved shoulder width (m)		SHP	0.50	2.50	1.68	0.71
Paved width (m)		PW	7.80	10.80	8.56	0.89
Unpaved shoulder width (gravel and untreated) (m)		SHD	2.00	10.00	3.55	2.06
Number of access per segment	Roadside Feature	N.ACCESS	0.00	3.00	1.02	0.73
Access density (number of access per segment length)		AD	0.00	6.66	1.08	1.14
Adjacent land use length (km)		LULN	0.00	0.45	0.15	0.14
Land use density (adjacent land use length per segment length)		LUD	0.00	0.62	0.14	0.15
Posted speed limit		PSL	40.00	110.00	89.28	11.99
	Categorical Variables					
Variable	Type of variable	Variable Symbol	Frequency of 0		Frequency of 1	
Paved shoulder width (1 if > 2 (m) ; 0 otherwise)	Geometric Feature	SHP01	80		58	
Unpaved shoulder width (1 if > 3 (m); 0 otherwise)		SHD01	76		62	
LU (1 if land use exists in the segment; 0 otherwise)	Roadside Feature	LU	61		77	
Land use type (1 if residential; 0 otherwise)		LUR	100		38	
Median type (1 if guardrail; 0 otherwise)		MT	59		79	
Roadside configuration type (1 if flat; 0 otherwise)		RSC	54		84	
Median and roadside type (1 if guardrail and flat; otherwise)		MTRSC	72		66	

5. Results and Discussion

Out of 138 existing segments, 108 were in tangents and 30 were in curves. Therefore, two modeling approaches were applied for analyzing operating speed. Before model estimation, the normality of speed data was evaluated using Kolmogorov-Smirnov (K-S) test. The tests were performed on tangent and curve segments and a statistics greater than 0.05 were obtained, implying the normal distribution of the data. To achieve better fitting results, several models (including with and without constant) were tested using SPSS.24 and the final models were selected based on the following criteria:

1. The high correlation between the independent and dependent variable
2. Lack of multicollinearity (using Durbin-Watson test)
3. The higher value of adjusted R-squared
4. The significance of independent variables at a confidence level of 95% (for the highest F statistics or lowest p-value)

To achieve the optimum model, several fits were obtained. Tables 2 and 3 show the results of the modeling obtained for the tangents and curves, respectively.

Table 2. Results of multivariable linear regression models for tangent segments

Variables \ Models	Model 1 Coefficient	Model 2 Coefficient	Model 3 Coefficient	Model 4 Coefficient
Constant	93.567 (t-value= 70.951) (p-value= 0.000)	86.609 (t-value= 69.795) (p-value= 0.000)	103.326 (t-value= 94.803) (p-value= 0.000)	92.02 (t-value= 16.790) (p-value= 0.000)
LN	3.22 (t-value= 4.422) (p-value= 0.000)	4.120 (t-value= 4.559) (p-value= 0.000)	-	6.403 (t-value= 6.872) (p-value= 0.000)
SLP	-0.485 (t= -3.855) (p-value= 0.000)	-0.624 (t= -3.970) (p-value= 0.000)	-	-
MT	-	-	-	7.589 (t-value= 5.493) (p-value= 0.000)
MTRSC	6.249 (t-value= 5.855) (p-value= 0.000)	7.696 (t-value= 5.944) (p-value= 0.000)	-	-
PW	-	-	-	-0.956 (t-value= -1.493) (p-value= 0.138)
PSL	-	-	-	-3.235 (t= -1.651) (p-value= 0.101)
AD	-4.307 (t-value= -6.788) (p-value= 0.000)	-	-7.138 (t-value= -8.713) (p-value= 0.000)	-
LULN	-8.041 (t-value= -2.620) (p-value= 0.010)	-	-4.012 (t-value= -0.928) (p-value= 0.355)	-5.203 (t-value= -1.338) (p-value= 0.183)
Model fit indices				
R-squared	0.730	0.564	0.436	0.661
F	55.706	45.338	41.038	39.695
Durbin- Watson	1.708	1.255	1.563	1.418
K-S test significance for operating speed in tangent = 0.130				

Table 3. Results of multivariable linear regression models for curves

Variables \ Models	Model 1 Coefficient	Model 2 Coefficient	Model 3 Coefficient	Model 4 Coefficient
Constant	96.368 (t-value= 46.727) (p-value= 0.000)	-20.476 (t-value= 0.952) (p-value= 0.350)	87.299 (t-value= 26.280) (p-value= 0.000)	66.641 (t-value= 3.453) (p-value= 0.002)
LN	-	-	-	36.453 (t-value= 4.807) (p-value= 0.000)
LOGLN	-	38.796 (t-value= 5.436) (p-value= 0.000)	-	-
SLP	-0.940 (t-value= -5.045) (p-value= 0.000)	-0.649 (t-value= -3.167) (p-value= 0.004)	-	-
MT	-	-	6.110 (t-value= 1.087) (p-value= 0.287)	-
RSC	9.141 (t-value= 4.730) (p-value= 0.000)	-	8.582 (t-value= 1.197) (p-value= 0.066)	-
PW	-	-	-	-0.612 (t-value= -0.38) (p-value= 0.700)
PSL	-	-	-	-0.045 (t-value= -0.683) (p-value= 0.501)
R	-	-	-	0.002 (t= -1.148) (p-value= 0.884)
C	-2.793 (t-value= -7.750) (p-value= 0.000)	-1.093 (t-value= -2.199) (p-value= 0.037)	-	-
AD	-1.729 (t-value= -3.282) (p-value= 0.003)	-	-1.938 (t-value= -1.828) (p-value= 0.079)	0.191 (t-value= -0.202) (p-value= 0.841)
LULN	-	-	-7.775 (t-value= -2.187) (p-value= 0.038)	-
		Model fit indices		
R-squared	0.854	0.836	0.423	0.667
F	37.961	45.768	4.770	13.003
Durbin- Watson	1.820	1.791	1.496	1.94
K-S test significance for operating speed in curves = 0.200				

As can be seen from the tables, several variables were used for modeling the operating speed. In the models presented for the tangents (Table 2), Model 1 (constructed with simultaneous utilization of roadside and geometric features) gives the optimum results. Model 2 (constructed with only geometric features) gives a lower R-squared compared to Model 1. Likewise, Model 3 (constructed using only roadside variables) has a lower R-squared compared to other models and even shows some insignificant variables. Finally, Model 4 (constructed with simultaneous utilization of several different roadside and geometric features) indicates some statistically insignificant variables and a low R-squared value.

In the models presented for curves (Table 3), Model 1 gives the better fitting results. It not only has an acceptable R-squared but also all variables of the model are statistically significant. Moreover, the model with using geometric (Model 2) or roadside variables (Model 3) gives poor results compared to other models. It is worth mentioning that the other model using both roadside and geometric features (Model 4) give unsatisfactory results.

In the selected models (Model 1 in Table 2 and Table 3), the applied variables were statistically significant as the statistics Durbin-Watson is around 2 for all models, which is a satisfactory value suggesting lack of autocorrelation in the residuals. Moreover, R-squared values for tangents and curves are 0.730 and 0.854, respectively, which are satisfactory results.

Among the roadside and geometric features, all variables used in modeling process were tested in different configurations (by changing the definition of the variables) in the form of dummy and continuous variables. Eventually, after several trials, the following variables were found statistically significant for tangents and curves models.

5.1 Segment Length

This variable, expressed in the kilometer, was found significant for tangents. The coefficient of this variable is positive, which suggest an improvement in operating speed with an increase in segment length. This result complies with the results of Hashim et al. (2016) and many other studies [Eboli et al. 2017; Esposito et al. 2011; Gargoum and El-Basyouny, 2016].

5.2 Slope

This variable is statistically significant in all of the selected models defined as the difference in the segment's height between two ends divided by segment's length (%). However, the coefficient of this variable is negative, which implies that vehicle’s speed decreases in uphill while it increases in downhill. This variable was also found significant in previous studies [Bassani et al.2015; Boroujerdian et al.2016; Esposito et al.2011; Garcia et al.2013; Gong and Stamatiadis, 2008]. Figure 1 presents the effect of slope on operating speed in both tangent and curve segments. This figure shows that with a 1 percent decrease in slope, the operating speed is reduced by 1 kilometer per hour in curves. Although, this value is 0.5 kilometer per hour for tangents model. As can be seen, the effect of slope on operating speed in curves is twice its effect in tangents and the speed in curves is more sensitive to slope comparing to tangent segments of the road.

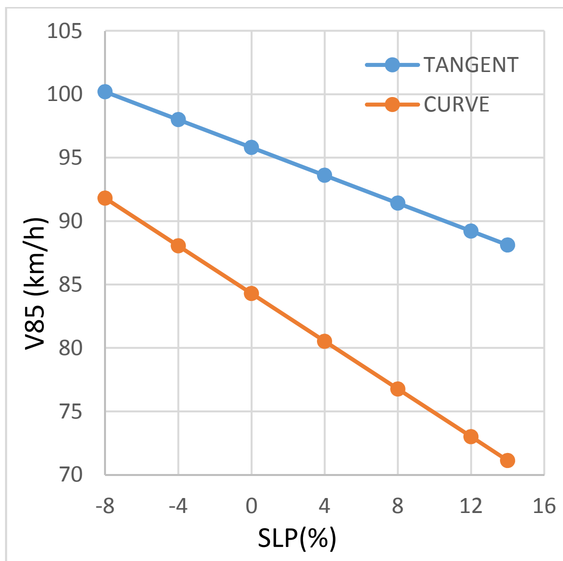

Figure 1. Variations of the slope with operating speed for tangents and curves

5.3 Median Type and Roadside Configuration Type

The studied highways in the present work are equipped with three types of medians (guardrail, New Jersey, and two-way left-turn lanes) and three roadside configuration type (cut, fill, and flat). To investigate the effect of these variables on operating speed, first three dummy variables were considered for median types and three ones were considered for the roadside configuration type. Eventually, a variable generated by multiplying of guardrail dummy variable and the flat roadside configuration dummy variable was found to be significant in the tangents. The coefficient of this variable is positive, suggesting that in roads equipped with guardrail median and flat roadside configuration drivers are more comfortable and drive at higher speeds. In the model proposed for curves, only flat roadside configuration dummy variable was found to be statistically significant. In this regard, Fitzpatrick et al. (2001) found median type as a significant variable.

5.4 Access Density

Access is one of the roadside variables which affects operating speed. This variable which is the number of accesses divided by the segment length was found significant in the tangents and curves models. The coefficients for access density in tangents and curves model are negative (-4.307 and -1.729 respectively) which implies that by an increase in the access density the entry and exit of vehicles increases, which is accompanied by the speed reduction along the segment. To investigate the effect of access density on operating speed, the sensitivity analysis for this variable was performed. Figure 2 presents the effect of changes in the access density on operating speed for tangents and curves. It shows that with one unit increase in access density, the operating speed is reduced by 4.2 and 1.7 kilometer per hour for tangents and curves respectively. Thus, operating speed in tangents is approximately 2.5 times more sensitive to access density than operating speed in curves.

5.5 Land Use

Land use is another roadside factor that affects the operating speed [Fitzpatrick et al.2001; Yagar and Aerde, 1983]. To investigate the effect of land use, as a roadside feature, adjacent land use length and adjacent land use density (which is the length of the adjacent land use divided by the length of the segment) were evaluated. Finally, adjacent land use length found statistically significant in tangent and curve models. This variable shows the land use area and, in turn, travel production rate. The coefficient of this variable is negative, which shows that by an increase in adjacent land use length drivers tend to drive more slowly. Although the variable land use type was also investigated, it did not show a significant effect in the regression models.

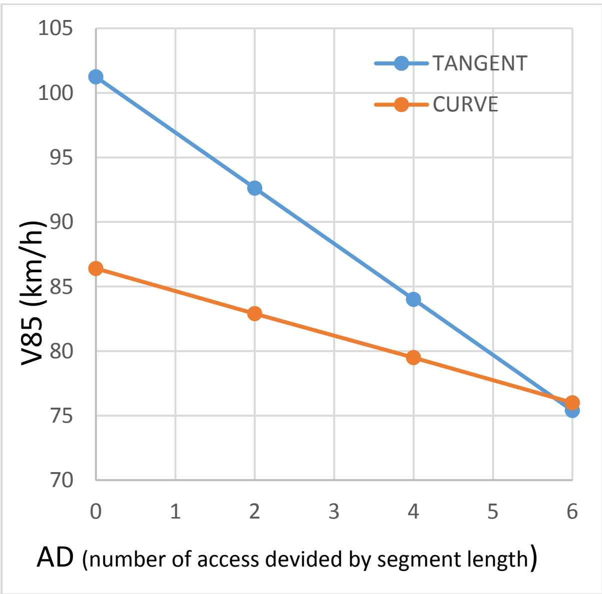

Figure 2. Variations of access density with operating speed for tangents and curves

5.6 Curvature

To evaluate the effect of the radius of each curve on operating speed, two variables, Curvature and radius, were evaluated. However, radius was found insignificant in the model. The curvature (which is the inversion of radius) has a negative coefficient, suggesting that a larger radius results in the reduced operating speed.

All of the above-mentioned variables were statistically significant. The coefficient of adjacent land use length in tangents model (-8.041) and the coefficient of flat roadside configuration (9.141) in the curves model have the highest coefficient in the models. The segment length, median and roadside configuration type show a positive effect on operating speed while the slope, access density, curvature, and adjacent land use length show a negative impact on operating speed. Hence, the regression model developed in this study for operating speed prediction in curves and tangents incorporates both roadside and geometric features. On the other hand, the comparison of two-lane highways speed prediction models in the literature [Fitzpatrick et al. 2001; Esposito et al. 2011; Bourujerdian et al. 2016; H.Hashim et al. 2016] with the proposed models in this study for four-lane highways indicates that two-lane and four-lane highways have very different operational condition. Thus, it can be concluded that the high R-squared value of these models makes them suitable tools for operating speed prediction in four-lane highways in the rural areas.

6. Conclusion

In this study, two linear regression model were presented based on geometric and roadside features. The speed data was gathered in two four-lane highways (Toureh-Boroujerd and Boroujerd-Khoramabad) in Lorestan Province, Iran. These 135 km-length highways were divided into 138 segments based on the roadside and geometric features and 13,800 spot speed was recorded using a speed gun. Two multiple regression models were proposed for tangents and curves with acceptable R-squared (0.730 and 0.854 respectively) using the operating speed as the dependent variable and roadside and geometric features (segment length, slope, the presence of guardrail and flat roadside configuration, access density, adjacent land use length, and curvature) as the independent variables. The coefficient of adjacent land use length in tangents model (-8.041) and the coefficient of flat roadside configuration (9.141) in the curves model have the highest coefficient in the models. The results of sensitivity analysis indicated that operating speed in curves compared to tangents has a more dependency on the slope (with a 1 percent decrease in slope, the operating speed is reduced by 1 and 0.5 kilometer per hour in curves and tangent model respectively); thus, the effect of slope on curves model is twice its effect on tangents model. The coefficient for access density in tangents and curves model are -4.307 and -1.729 respectively. Besides, the sensitivity analysis of this variable showed that operating speed in tangents is approximately 2.5 times more sensitive to access density than operating speed in curves.

In the presented models in this study, both geometric and roadside features were considered for operating speed modeling simultaneously which to the best of the authors' knowledge were not considered simultaneously in the previous studies. The results of this study demonstrate that in addition to the geometric features, roadside features also affect operating speed.

As a suggestion for further studies, it is recommended studying other factors such as latent variables. Moreover, it is suggested studying the mutual effects of these variables on each other and their simultaneous effect on operating speed prediction.

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